Ocean Applications of a Dedicated Gravity Mission

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C. Wunsch
and V. Zlotnicki,
for the Organizing
Committee
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C.Wunsch and
V.Zlotnicki)

Measuring Ocean Bottom Pressure Changes from Space: Report of a Meeting

- Motivated by GRACE's promise to provide monthly estimates of the Earth's gravity field, over 5 years, with extraordinary precision.
- Monthly changes in ocean bottom pressure, directly relate to ocean bottom currents
- This idea, that elements of the ocean circulation, manifesting themselves at the seafloor, can be measured from space, led oceanographers and geophysicists to consider how such measurements can best be interpreted, how the data might best be analyzed, and how to optimize the results.
- NASA and the U.K.'s Proudman Oceanographic Laboratory sponsored a workshop to explore the use of such data in oceanographic applications.
- Held April, 1999, at the Royal Society, London.

This presentation summarizes Report, adds new information.

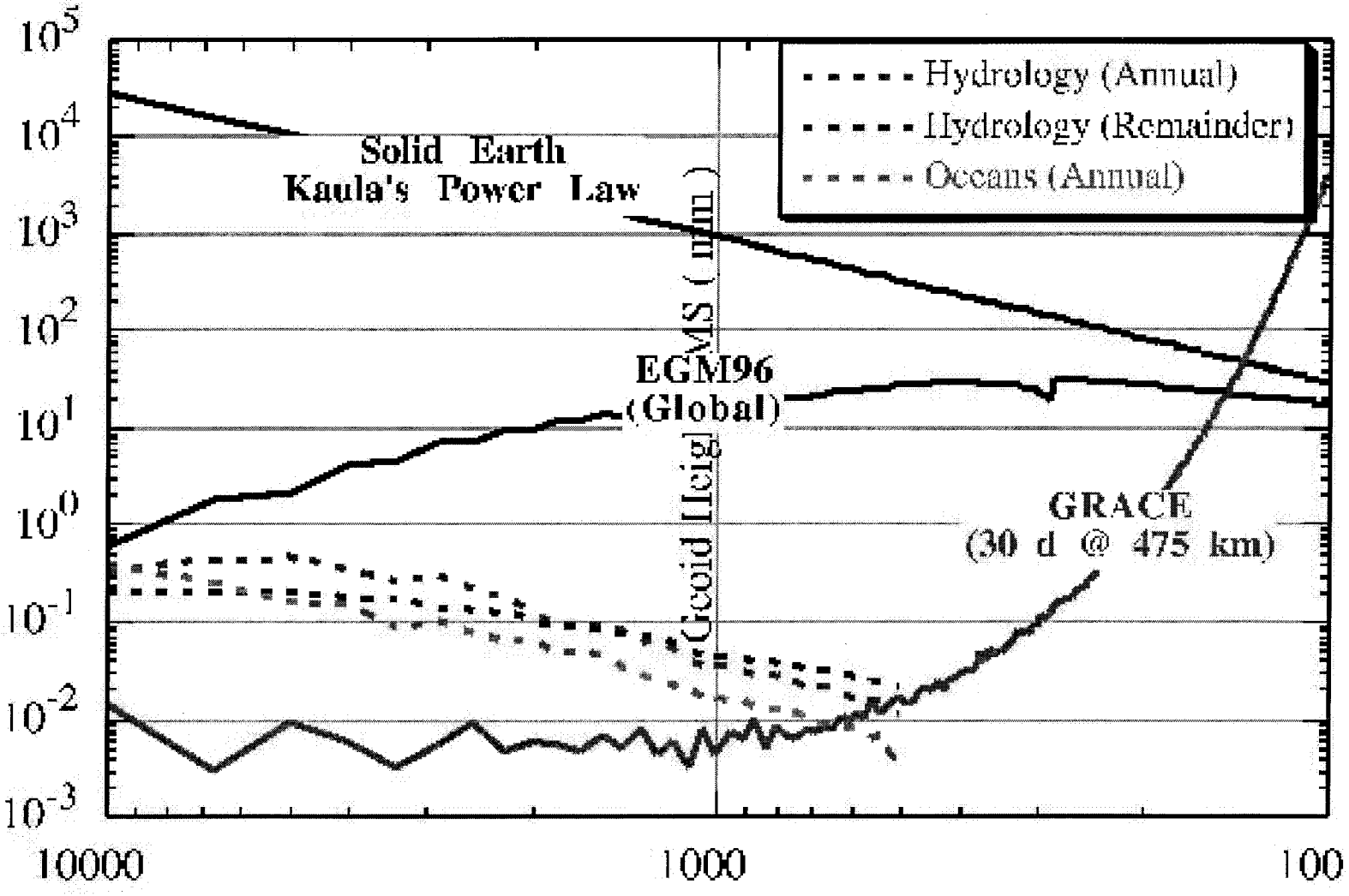
CHAMP, GRACE, GOCE

CHAMP: 2000 launch. Gravity and Magnetic. One satellite: GPS, accelerometer.

GRACE: 2001 launch. Gravity, Atmosph occult. Two satellites: range rate, GPS, accelerom. 500-300 km high, 5 year.

GOCE: 2003 launch. Gravity only. Gradiometer, GPS/GLONASS. 250 km high, 8-16 months.

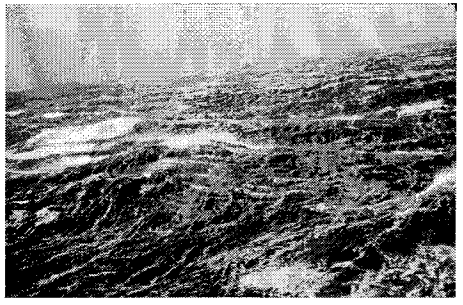
Spectrum of Signal & Expected GRACE Errors
(Instrument Noise Prediction for 30 days @ 475 km)

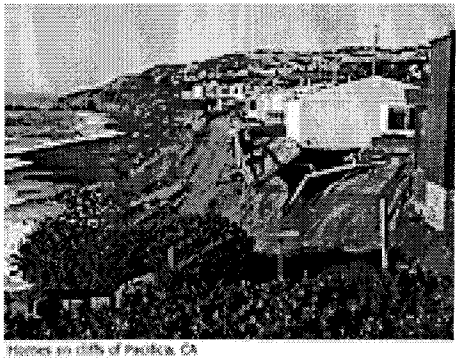


Bettadpur, GRACE PRR (Apr 2/3, 1998)

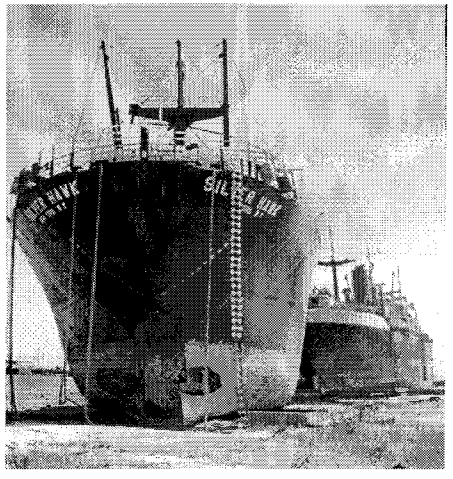
Ocean Importance

- Earth is an ocean planet. 70% of its surface is ocean, not land.
- The Ocean is critical to life. 50 % of the world's population lives within 100 km from the coasts. Humans depended on the oceans for food, transportation and warfare for hundreds of years.
- Understanding the ocean and knowing how to exploit it have been key factors in the evolution of human civilization.
- The ocean also plays a key role in climate and weather. Time scales include the cycles of ice ages (>10,000 years), global warming (10-100 years), El Niño (3-5 years), and severe storms and hurricanes (days).



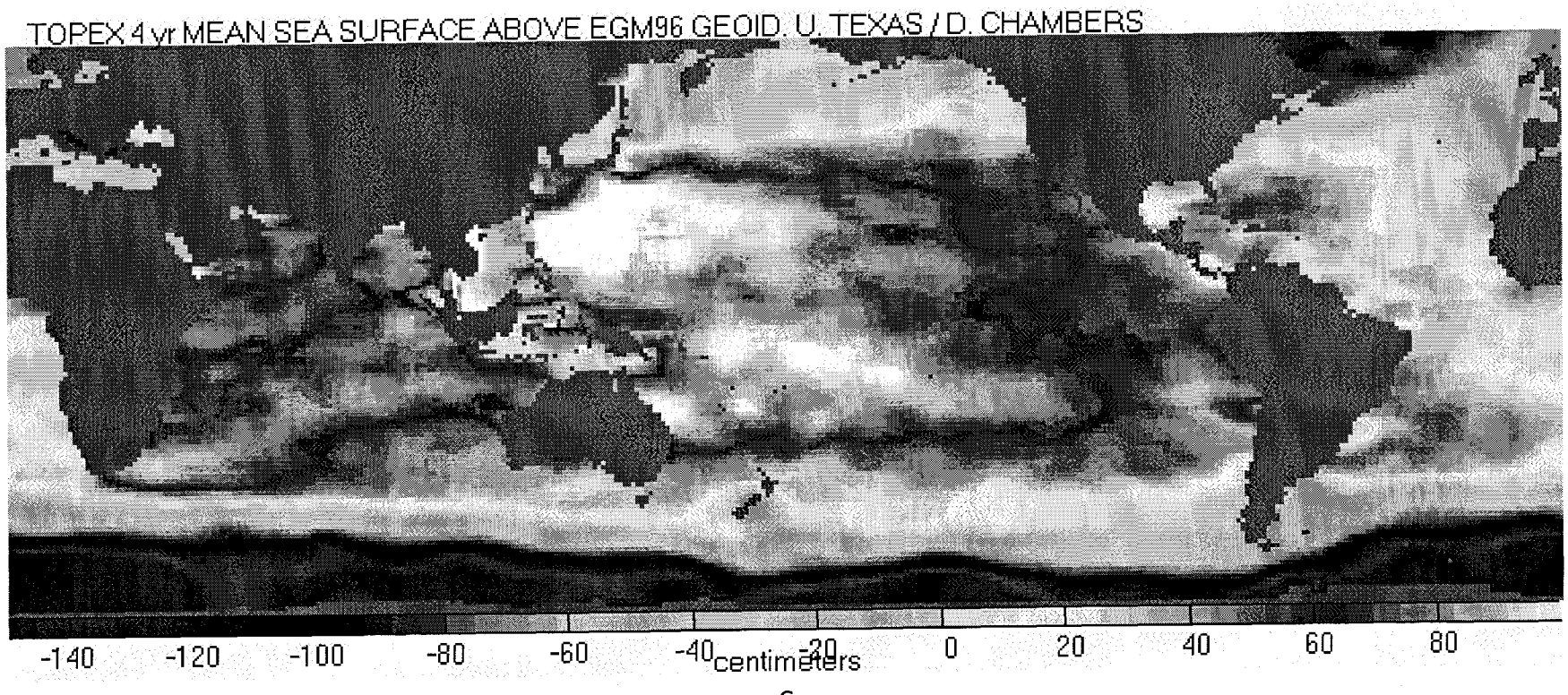


Homes on cliffs of Pacifica, CA



Ocean Circulation and Oceanic Geoid Data

- Geostrophic Surface current = gradient_H(Altimetry–Geoid)



(d/dt)(Gravity over Oceans)
(d/dt)(Ocean Bottom Pressure)

- (d/dt) (weight of atmosphere+ocean column)
- Does not need modelling out the atmosphere, as land & ice applications do.
- Assumption: 'solid Earth' does not change. But, rebound, earthquakes, plate tectonics.
- Resolution: leakage from (d/dt) of land water, ice changes.

Dealiasing High Frequency Variability

- 30-day gravity estimates
  => Need to remove shorter period variability before solving for gravity.
- Ocean
  - Tides TBD cm
  - Wind & Pressure effects
    - 'Inverted Barometer' TBDcm
    - Barotropic model IB+TBDcm
    - Baroclinic model
- Atmosphere
  - NCEP or ECMWF

In situ observations of sea floor pressure variations

- Bottom Pressure Recorders: Few. Drift. 1-year max.
- Current meter moorings: equivalent pressure gradient.
- 'Navy Acre': fully instrument a 500x500 km area.

How accurate are the analyses of atmospheric mass change

- Data coverage is excellent over the American, European and Asian continents and the North Atlantic, less good in the N. Pacific and Indian Oceans and over Africa; very poor in the S. Pacific and S Atlantic basins, worse in the Southern Ocean and over Antarctica.
- The discrepancy between 6 hour NCEP forecasts and observations of surface pressure is about 1.5 mbar (VanDenDool)

How accurate are models of oceanic tides

- Tide model accuracy -> 1 cm RMS
- There is a limit to predictability near 1 cm owing to random components in the tidal signals.
- D. Cartwright (Southampton Oceanography Centre, UK, SOC) emphasized the different parts of tidal signals seen by altimeters, tide gauges, and bottom pressure recorders. For example, odd-order baroclinic modes have an inverse relationship in bottom pressure and sea surface height da
- Working Group to study and advise.

Physical implications of oceanic bottom pressure fluctuations

- (C. Hughes) A net meridional transport in the Ekman layer causes a geostrophic deep return flow whose interaction with the bottom topography produces bottom pressure torques (spin torques) which alter the Sverdrup balance. When zonally integrated, the spin torques can balance the wind stress curl without the need to invoke a viscous boundary layer to do so.
- Using the OCCAM model Hughes found that in the ACC, the main balance is between the integral of pressure and topography against the wind stress, a balance that occurs in a few days, with other terms being much smaller.
- Bottom pressure is crucial in understanding the circulation.

How accurate are existing oceanic general circulation models

- F. Bryan discussed the ability of ocean general circulation models to reproduce bottom pressure. Results from a version of the POP model, in both barotropic and baroclinic configurations, with wind only or wind and pressure forcings. The model is volume conserving, so a correction is made by an artificial layer to conserve mass at each instant.. He recapitulated the BEMPEX comparisons and in general, the model motions are too weak. The difference between barotropic and baroclinic model results at one BEMPEX site is about 0.5 mb At a point near the equator, there is an annual cycle in the difference between the barotropic and baroclinic models. Globally the RMS difference between barotropic and baroclinic sea level is about 0.5